Remote Sensing for Forest Health Monitoring: Innovations and Future Directions

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Forests play a crucial role in maintaining biodiversity, carbon storage, and ecosystem stability. However, they are increasingly threatened by climate change and extreme weather events, resulting in drought stress, insect outbreaks, and tree diseases. Traditional monitoring methods are often slow and labor-intensive, making it difficult to detect forest damages and early signs of forest stress. Fortunately, advances in remote sensing technology are transforming our ability to assess and protect forests from individual-tree scale to landscape scale.

This lecture explores how cutting-edge remote sensing techniques—such as multispectral and hyperspectral imagery, satellite and drone imagery, and Light Detection and Ranging (LiDAR)—enable the early detection and accurate mapping of forest disturbances. My research has focused on leveraging these technologies to improve forest health monitoring. For example, we have explored the potential of satellite-based remote sensing for large-scale forest stress mapping. By utilizing Sentinel-2 imagery, we have successfully identified spectral indicators that reveal early forest stress patterns, enabling cost-effective and continuous monitoring over large forested areas. Additionally, by analyzing drone-based multispectral and hyperspectral data, we have significantly improved the early detection of spruce bark beetle attacks, increasing detection rates from traditional methods’ 28% to over 80%. Similarly, we have demonstrated that multispectral drone images can be used to estimate tree vitality loss due to pine needle disease, providing valuable insights for forest managers.

Looking ahead, my future research will focus on deepening our understanding of the spectral response of trees to different stressors and the physiological changes associated with forest decline. By integrating hyperspectral and multispectral remote sensing, temporal and spatial analysis techniques with physiological and biochemical data, we aim to refine the identification of early stress indicators and differentiate between various stress types such as drought, insect infestation, and disease. Advancements in these techniques will enhance near-real-time forest monitoring, allowing for more precise and proactive forest management strategies in response to climate change. Ultimately, this research will contribute to developing operational remote-sensing tools that support sustainable forestry and ecosystem resilience.